Prince George Forest Region

Forest Resources & Practices Team

March 1997
Note #PG-12-1

RESEARCH NOTE

Cumulative early losses in Douglas-fir and lodgepole pine plantations may be a "red flag" for silviculturalists recommending lower initial plantation densities.

EXPERIMENTAL PROJECT 660 30-year Progress Report
Buckhorn Installation

by Dave Coopersmith, Marian McLellan and John Stork

The Experimental Project 660 (EP 660) is a long term forest research study examining the influence of planting density on the growth performance of white spruce, Douglas-fir and lodgepole pine.

The Buckhorn Ridge study area is one of three EP 660 installations in the region surrounding Prince George. The three study areas were created at the same time, using the same study method and evaluation procedures. Details on the EP 660 study rationale and methodology are reported in Research Note PG 12 - "Experimental Project 660 - Overview of Three Experimental Installations", available in this publication series.

This Research Note reports the results for the first 30 years of monitoring at the Buckhorn Ridge research site. Results from the two companion studies are also reported in this series as : Research Note PG 12-2 "Experimental Project 660 - Bobtail Road Installation: 30 Year Progress Report" and Research Note and PG 12-3 "Experimental Project 660 - Chilco Creek Installation: 30 Year Progress Report."

The Buckhorn Ridge Study Site

The Buckhorn Ridge research site is located approximately 45 kilometres southeast of Prince George along the Buckhorn Forest Service Road. The site is located within the sub-mesic to mesic association of the Fraser Basin variant of the Moist Cool Central sub-zone of the Sub-Boreal spruce biogeoclimatic zone (SBS $_{mk1-05}$, DeLong and Tanner, 1996) Mean elevation of the study area is approximately 900 metres.

The Buckhorn area is underlain by Brunisolic Gray Luvisols developed from medium to moderately-fine textured, gravelly glacial till parent material (Dawson 1989). This area, along with much of the Fraser River basin, has a root-restricting compacted Bt horizon at approximately 30 centimetres depth in the soil profile. The soil on the ridge itself are shallow, with outcroppings of bedrock exposed at various places within the plot. Frequent fires in the Buckhorn area have removed much of the organic layer more typically found under mature forest stands in and around Prince George. A very thin, poorly developed Mor forest floor is present under most of the juvenile stands on this site.

The original white spruce and Douglas-fir stands were logged in 1954/55. Parts of the present research area were burned in the small Buck fire of 1957. In 1958, the first spruce espacement trial in the central interior of the province was established on the site (EP 549), which was later wiped out by the huge Grove fire in August 1961. The trial was reestablished near the original site in the summer of 1967, and expanded to include lodgepole pine and Douglas-fir. It became known as the EP 660 study.

The Buckhorn Ridge area has been a prime area of interest for research scientists and operational silviculturalists. More than 12 research trials have been established there, including three direct seeding trials, bullet container planting trials performed by the CFS, pine thinning and fertilization research and lodgepole pine gall rust pathological studies.

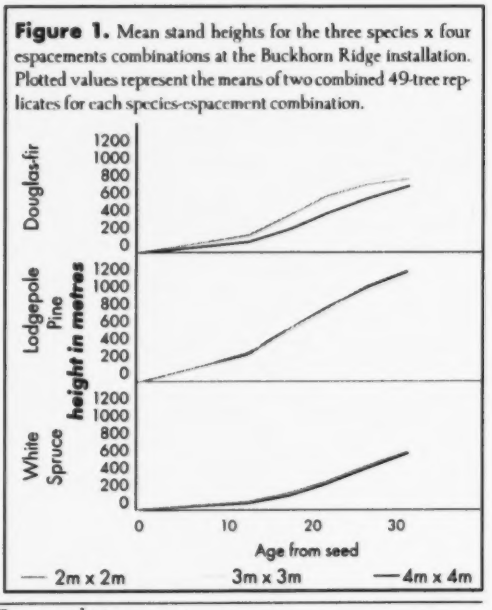
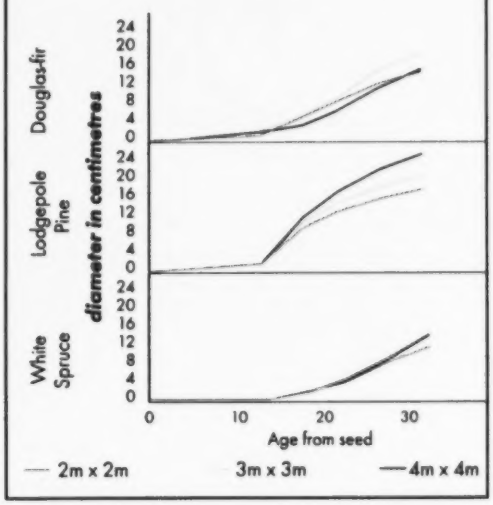


Figure 1. Mean stand heights for the three species x four espacements combinations at the Buckhorn Ridge installation. Plotted values represent the means of two combined 49-tree replicates for each species-espacement combination.

Figure 2. Mean stand diameter dynamics for the three species x four espacements combinations at the Buckhorn Ridge installation. Plotted values represent the means of two combined 49-tree replicates for each species-espacement combination.

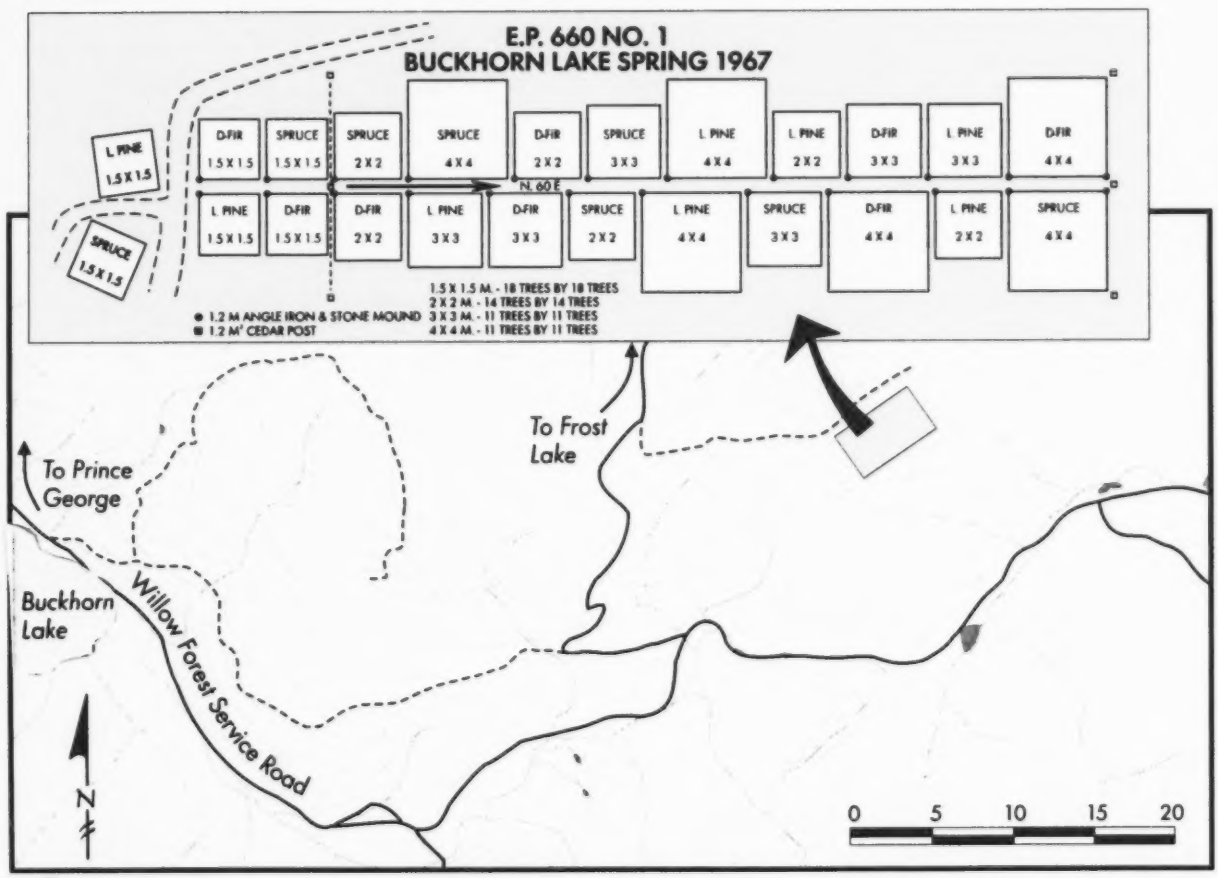


Results and Discussion

Height and Diameter Growth

The stands at Buckhorn Ridge are changing rapidly. In the highest density (closest espacement) lodgepole pine and Douglas-fir stands, the crowns of the trees have closed and are starting to lift. This indicates that these stands now fully occupy the site and that competitive interactions between trees are intensifying. The more narrow crown form and greater shade tolerance of white spruce means that the crown of these trees have not yet started to lift.

Clear and statistically significant species differences are evident in the height growth of the three species. Lodgepole pine is the tallest species, at an average height of approximately 11.4 metres, followed by Douglas-fir at approximately 7.8 metres average height and white spruce at approximately 5.9 metres average height. Both lodgepole pine and Douglas-fir have grown very well on the warm, well-drained soils of this site.



Ministry of Forests, 5th Floor, 1011 - 4th Avenue, Prince George, BC V2L 3H9 Telephone: (250) 565-6100 Fax: (250) 565-4349

The initial growth rate of white spruce has been quite slow relative to the other two species. This is not surprising, since the south-western aspect and sub-mesic nature of this site would not be favourable to spruce growth. Slow initial growth of bare-root spruce stock types was also typical for the time, leading to the early abandonment of this stock type in favour of container-grown seedlings. However, the spruce are now growing well, as much of the competing alder and willow has died back, and many individual spruce trees are as tall or taller than their neighbouring Douglas-fir and lodgepole pine. The spruce have also suffered much less damage in recent years compared to the lodgepole pine and Douglas-fir.

Although less clear than for the species effect, espacement did have a significant effect on height growth, and appears to have had a lesser effect on diameter growth. There was no difference between the 2.0 metre and 3.0 metre espacements. Trees planted at the widest 4.0 metre espacements were the shortest for this installation. The species trend towards taller trees at closer espacements was most evident in Douglas-fir, followed by lodgepole pine. White spruce showed the least evidence of increasing tree heights with closer spacings.

As would be expected, trees at closer espacements tended to have smaller diameters. This was most evident in lodgepole pine where the trees in the widest espacement were largest, while those in the closest espacement were smallest. These trends were much less clear in Douglas-fir and white spruce.

Figure 3. Mean stand total volumes for the three species x four espacements combinations at the Buckhorn Ridge installation. Plotted values represent the means of two combined 49-tree replicates for each species-espacement combination.

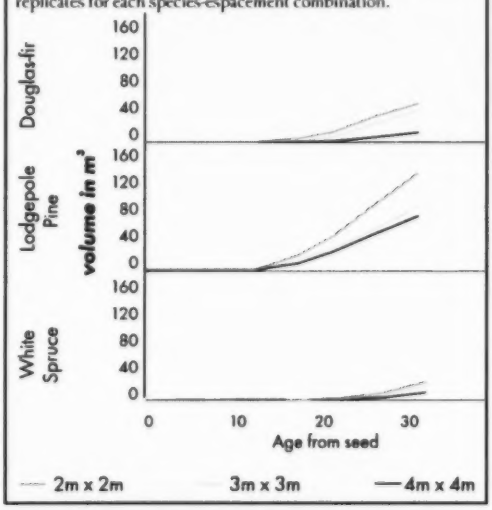
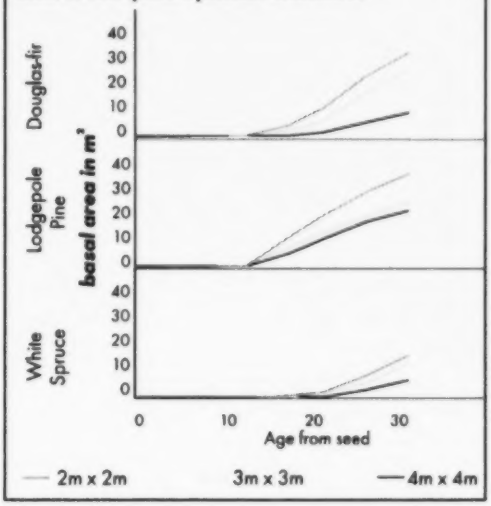


Figure 4. Mean stand basal areas for the three species x four espacements combinations at the Buckhorn Ridge installation. Plotted values represent the means of two combined 49-tree replicates for each species-espacement combination.



Volume and Basal Area Development

Volume and basal area estimates were produced from height and diameter data utilizing equations for juvenile plantations from Kovats (1977). Similar trends to those observed in height and diameter growth were also seen in basal area and volume development. There are again clear species differences between the three species at Buckhorn, with lodgepole pine having the greatest volume and basal areas at a given espacement, followed by Douglas-fir and white spruce (Figures 3 and 4). Basal area is now near greater than 32 m^2/ha for the closest espacements of lodgepole pine, and nearly 30 m^2/ha for the equivalent espacement of Douglas-fir. The widest 4m x 4m espacement of lodgepole pine has only 60.1% of the total basal area of the closest 2m x 2m espacement. For Douglas-fir, the 4m x 4m treatment contains only 27.6% of basal are of the 2m x 2m treatment. White spruce is well below the basal areas of both Douglas-fir and lodgepole pine, with the best-stocked spruce stand now at approximately 25 m^2/ha basal area.

Total volumes are now developing rapidly in most stands at Buckhorn. The highest volumes of pine and Douglas-fir are again found in the closest espacement, where volumes for lodgepole pine are nearing 145 m^3/ha. The equivalent volume for Douglas-fir is approximately 64 m^3/ha. White spruce has again lagged far behind both lodgepole pine and Douglas-fir. Maximum volumes in white spruce are at approximately 31 m^3/ha.

These data reinforce the well-known silvicultural observation that changes in stand density have greater effect on stem diameter than on tree height (Perry 1985).

These data also demonstrate that shade intolerant species such as lodgepole pine tend to show these espacement effects sooner than more shade tolerant species such as Douglas-fir and white spruce. In some cases, going to wider espacements will result in basal areas and total volumes that are less than 25% of those achievable at higher planting densities. It must be remembered however that these calculations are for total rather than merchantable volumes. Differences in volumes tend to be less between high density and low density stands where merchantable volume rather than total volumes are calculated (Pollack *et al.* 1992).

Middleton *et al.* (1995) have found that production of premium structural and appearance grades of lumber were optimum at approximately 1100 stems/ha of lodgepole pine at final rotation (95 years) on good sites. Moving to densities that were either higher of lower from the 1100 sph optimum at final rotation resulted in significantly higher levels of poor quality lumber recovery. At densities higher than the optimum, average tree diameter was too small to optimize high quality timber recovery. At lower densities, poor self pruning resulted in large numbers of knots and large percentages of juvenile wood which also lowered quality wood recovery. This would suggest that initial planting densities should be much greater than current levels if significant plantation losses are expected.

Incidence of Diseases, Pests and Abiotic Damage

Data for diseases, pests and pathogens have been summarized for the 1986 and 1996 measurement only (Tables 1 and 2). Significant abiotic damage has occurred since 1986, especially to Douglas-fir.

Incidence of Diseases

Of the three species planted in the EP 660 trial, lodgepole pine has had by far the most disease and insect pest problems. The most common pathogen influencing lodgepole pine has been Western gall rust (*Endocronartium harkenssii*) which has infected most of the lodgepole pine.

The infection levels of Western gall rust evident at the 20 year evaluation appear to have increased from the 15 year assessment, and there are greater levels of branch infection at wider planting espacements. There was a dramatic decrease in the number of stem galls noted between the two evaluations, this is because many of the trees with prominent stem galls in 1981 would have died by 1986. The stem and branch gall infection estimates were made on live trees only. Secondly, a tree with multiple stem problems (stem galls and bark peeling due to small mammals) would probably be noted by only the more serious injury. These two factors probably account for the large decrease in noted stem galls between the two evaluations, and the low number of stem galls in general.

TABLE 1. Summary of the percentage of stems within the Buckhorn plantations that showed snowshoe hare (hares) and red squirrel (squirrel) damage and were dead or broken topped by the 1986 evaluation. Data for each species-espacement combination are for all trees, both live (trees with visible bark peeling) and dead (where cause of death could be ascribed with certainty to snowshoe hares or squirrels). Species codes: Sw = white spruce, Pl = lodgepole pine, Fd = Douglas-fir.

Damage Caused		Species	Plantation Espacement (m)			
			2.0 x 2.0	3.0 x 3.0	4.0 x 4.0	Species Average
hares	1981	Pl	22.4	24.5	19.4	24.2
	1986	Pl	39.0	8.0	24.0	25.6
	1986	Sw	0	0	0	0
	1986	Fd	0	0	0	0
squirrel	1996	Pl	56.1	61.2	53.1	48.2
	1996	Sw	0	0	0	0
	1996	Fd	0	0	0	0
dead	1996	Pl	20.4	18.4	18.4	19.1
	1996	Sw	17.3	18.4	25.5	13.6
	1996	Fd	1.0	6.1	19.4	6.6
damaged tops	1996	Pl	15.4	12.5	23.4	14.6
	1996	Sw	33.3	41.3	50.7	40.6
	1996	Fd	52.6	64.1	63.3	52.7

In addition to the western gall rust infections, the lodgepole pine stands also contained minor amounts of Atropellis canker (*Atropellis piniphila*) and stalactiform blister rust (*Cronartium coleosporioides*) infection.

Insects

Numerous insect pests infest the stands of the three installations including the spruce leader weevil (*Pissodes strobi*), the spruce gall aphid (*Adelgies cooleyi*), the lodgepole pine leader weevil (*Pissodes terminalis*) and Warren's root collar weevil (*Hylobius warreni*).

There are moderate endemic levels of spruce leader weevil on the white spruce ,

while virtually every spruce in the plantation has been attacked to some degree by spruce gall aphid. These pests are probably causing some height growth losses and are responsible for form defects within these stands. The damage from the terminal weevils was much less severe in the lodgepole pine than in white spruce.

Animals

The most serious pest problem evident in the EP 660 stands has been cambial feeding on lodgepole pine by red squirrels (*Tamiasciurus hudsonicus*) and snowshoe hares (*Lepus americanus*). Animal damage to white spruce or Douglas-fir has been rare. Only a few examples of hare and squirrel stem damage have been observed on these species, along with some minor ungulate browsing to the leaders and branches of both species.

Most of the snowshoe hare damage to lodgepole pine occurred in the earlier years of plantation establishment, when stem diameters were still quite small. Up to and including the 1981 evaluation, damage to pine stems by snowshoe hares was viewed as the most serious pest problem in the EP 660 plots. However, little new hare damage to the larger pine stems has been observed in the most recent measurements.

Unlike the snowshoe hares, red squirrels prefer larger diameter pine trees. Red squirrel feeding damage is now the most common injury in the pine plantations. The squirrels have concentrated their feeding on the most vigorous pine stems in the plots, establishing a feeding area around a central tree. Within these feeding areas, heavy scarring damage has been recorded. Many of the attacked trees have been nearly girdled, and they are likely to die in the future as a result of these attacks. Even small wounds may act as entry courts for future disease infections.

It is likely that the small plot size of the EP 660 installations, surrounded as they are by extensive areas of unthinned natural pine stands, attract large numbers of squirrels and results in higher than expected damage levels. Sullivan *et al.* (1996) has found an inverse relationship between stand density and squirrel damage in lodgepole pine stands throughout the interior of BC. Low density stands do not offer squirrels as much cover as high density stands, so it would appear that the squirrels are preyed on more heavily in thinned areas, especially by hawks and owls. Higher predation on the squirrels leads to less damage in pine. By contrast the EP 660 stands have lots of dense pine stands surrounding them, offering the squirrels ample shelter from predators.

Abiotic Damage

Since 1991, abiotic events have had the greatest impact on the stands at all three EP 660 sites. During the 1986 evaluation, Douglas-fir appeared to be rapidly catching up to lodgepole pine in both total height and average diameter, and researchers expected that the Douglas-fir would be as large or larger than the pine in most plots by the 1991 evaluation. This has not happened.

Since 1989, a series of extreme weather events have affected the EP 660 stands. The Douglas-fir were damaged more than the other two species. During an early-January arctic outbreak event in 1989, the sudden drop in temperature resulted in dead top buds and top dieback for most of the Douglas-fir and large amounts of spruce. An early spring hail storm in 1991 also resulted in dead and broken tops throughout many of the EP 660 plantations. Again, the damage has been heavier in Douglas-fir than in the other two species.

The extent of top damage in the Douglas-fir stands at the Buckhorn site is surprising for several reasons. The Buckhorn site slopes dramatically to the southwest. It sheds cold air quite well. Yet it would appear that the Douglas-fir at Buckhorn have been repeatedly damaged by frost events. It is possible that the provenance of seed used at the Buckhorn trial was particularly susceptible to frost damage, or that it is "off-site" at Buckhorn. None of the Douglas-fir naturals in the surrounding stands show the same level of damage as do the Douglas-fir plantations at the Buckhorn site of EP660.

The net result of these events has been that most of the Douglas-fir have lost five to seven years of top growth. These losses have undoubtedly affected the Douglas-fir average top height data. Indeed, an examination of the graphs of Douglas-fir and lodgepole pine average diameter growth shows that Douglas-fir is now as large or larger in diameter than equivalent lodgepole pine at similar espacements. This is also clear if we examine the graphs for basal area. Unlike volume calculations, basal area is not affected by top height. There is little difference between the two species in terms of site occupancy.

The tallest undamaged individuals of both species are now greater than 14 metres tall. Had the Douglas-fir managed to escape these devastating abiotic events, it would likely be the leading species in terms of both volume, height and diameter at Buckhorn ridge now.

As a final note, it does not appear that the abiotic damage is finished in the Douglas-fir plots. Many of the Douglas-fir now have a very flat topped appearance. Because of this, they catch much greater amounts of snow, making them very susceptible to snow breakage. When we visited the Buckhorn site in early December of 1996 following a heavy snowfall, we noticed several newly broken Douglas-fir in the plots.

Conclusions

- Although probably greater than would be observed operationally, the levels of damage observed in the lodgepole pine espacements at Buckhorn are alarming. Where cyclical pests (hares and squirrels) and endemic diseases are prevalent, initial establishment densities will have to be higher in order to achieve wood quality objectives at final rotation. A target density of 1100 stems/ha at final rotation would appear to be a reasonable goal.

- Douglas-fir shows very good growth potential on some sites in the SBS_{mk}. It is prone to much less damage from biotic sources. Douglas-fir rarely grows in pure stands in nature, and is moderately shade-tolerant in the SBS. Planting Douglas-fir in a mixture, either with other conifers or with a broadleaf species such as paper birch may afford this species greater degrees of protection from abiotic events.

Natural Douglas-fir regeneration near Tabor Mtn.

- Particular attention should be paid to said provence if Douglas-fir is to be utilized. Selecting provence with a high resistance to frost damage is a necessity in the SBS.

- White spruce has lagged behind both Douglas-fir and lodgepole pine in terms of height and diameter growth since the first evaluation at Buckhorn in 1977. Much of this poor initial growth can be accounted for by the poor initial growth performance of the 1967 bare-root stock. Current container-grown types perform much better after outplanting than do their earlier bare-root cousins. The long-term resistance of white spruce to abiotic and biotic damage events (in particular the rusts that plague many pine plantations) may outweigh the slower initial growth that this species has shown.

Literature Cited

Dawson, A.B. (1989). Soils of the Prince George - McLeod Lake area. Report No. 23, British Columbia Soil Survey. Ministry of the Environment Technical report 29. BC Ministry of Agriculture and Fisheries, Soils Branch, Victoria, BC. 219 pp.

DeLong, C.D. and D. Tanner, (1996). A field guide for site identification and interpretation for the southeast portion of the Prince George Forest Region (draft). Land Management Handbook # 29. British Columbia Ministry of Forests, Research Branch, Victoria, BC. 360 pp.

Kovats, M. (1977). Estimating juvenile tree volumes for provenance and progeny testing. Canadian Journal of Forest Research 7: 335 - 342.

Middleton, G.R., L.A. Jozsa, B.D. Munroe, and P.Sen (1996). Regional comparison of wood density and knot size in low stand density lodgepole pine. Forintek Canada Corp. Special Publication No SP-36, Vancouver B.C. 27 pp.

Perry, D.A. (1985) Competitive processes in Forest Stands. pp 481-506 In, M.G.R. Cannell and J.E. Jackson (eds.) Attibutes of Trees as Crop Plants. Institute of Terrestrial Ecology. Cambria, Great Britain. 592 pp.

Pollack, J.C., W.C. Johnstone, K.D. Coates and P. LePage (1992). The influence of initial spacement on the growth of a 32-year-old white spruce plantation. Unpublished report of EP537. BC Ministry of Forests, Prince Rupert Region. 35pp.

Sullivan, T.P., W. Klenner, and P.K. Diggle (1996). Response of red squirrels and feeding damage to variable stand density in young lodgepole pine forest. Ecological Applications 6(4): 1124-1134.

For further information

Dave Coopersmith,
RPF, Research Silviculturalist
Prince George Forest Region
1011-4th Avenue,
Prince George, BC, V2L 3H9
ph 250-565-6212 fax 250-565-4349
email: dcoopers@mfor01.for.gov.bc.ca